In this example the time has in no case been taken closer than seconds, as this is more than sufficiently accurate for the purpose. Practically a watch error of $\pm 2^m$ would be perfectly allowable, as it would not vitiate the adjustment by as much as a minute of arc, an insignificant amount.

The principal advantage of this method of adjustment is that it does away altogether with the use of the finely divided declination circle. As the reading of this circle is always the most laborious and lengthy part of any ordinary method of adjustment, and is the especial dread of amateur astronomers, the importance of this point need not be dwelt on.

NAPA COLLEGE, NAPA, CAL.,
March 21, 1893.

MISCELLANEOUS OBSERVATIONS OF *NOVA AURIGÆ.*

BY W. W. CAMPBELL.

(*a*). In the *Monthly Notices of the Royal Astronomical Society* for January Dr. ISAAC ROBERTS gives the following account of his attempts to photograph any nebulosity that may be connected with *Nova Aurigæ:*

"A photograph of the region of *Nova Aurigæ* was taken on October 3, 1892, with the 20-inch reflector, and exposure of 110 minutes, upon which the *Nova* appears as a star, as well defined as any of the other stars, which are very numerous, on the plate. There is no trace of nebulosity surrounding the *Nova*, or in its vicinity, and there is no feature about it suggestive that it is different from other stars. The diameter of its photo-image measures 21 seconds of arc, and about 85 seconds distant from it, on the north-following side, is a star, the photo-image of which measures 23 seconds of arc; the *Nova* is therefore 2 seconds in diameter less than the star.

"On December 25, 1892, another photograph was taken of the same region, with an exposure of 20 minutes, upon which the *Nova* has a photo-image of 13 seconds of arc, and the star referred to has a diameter of 16 seconds.

* * * * * *

"So far, therefore, as the evidence obtained by the eleven photographs which I have taken between the date of the appearance of the *Nova* and December 25, there is nothing upon them indicative of a disturbance, such as we might expect to see recorded if a body of the magnitude and velocity of the *Nova* had rushed into a nebula, or into a swarm of meteors." * *

Negatively, these photographs are of great interest, for several reasons:

(1). In *Astronomische Nachrichten* No. 3118 Prof. SEELIGER explained the observed spectrum of *Nova* during February and March, 1892, on the hypothesis that a very faint or dark body had passed swiftly through one of those large tenuous nebulosities which the excellent photographs obtained by Herr MAX WOLF of Heidelberg show to be very extensive in many parts of the sky. If such a nebula surrounds *Nova*, it must be exceedingly faint to have escaped detection by Dr. ROBERTS' telescope with long exposure.

(2). The smaller image shows it to be considerably fainter photographically than the star 85 seconds distant, though visually the *Nova* is at least half a magnitude brighter than the star. These results had also been reached here by Prof. SCHAEBERLE, and at Greenwich. They were to be expected from the distribution of the light in its nebular spectrum, nearly all the light falling at the wave lengths 575, 500, 496 and 486, which are in regions only slightly actinic.

(3). In the 36-inch equatorial the *Nova* is plainly seen to be nebulous and about 5 seconds of arc in diameter. As we construe Dr. ROBERTS' paper, he contends from his photographic evidence that the *Nova* is not nebulous. Since the photo-images are from 13 to 21 seconds in diameter, we do not see how they can have any bearing upon the question of the character of the *Nova*, which is probably not much over 5 seconds in diameter. I would suggest that the value of the evidence be tested by photographing some planetary nebula resembling the *Nova* in magnitude and structure, for example, N. G. C. 6790, and comparing the nebular image obtained with that of a star slightly fainter (visually).

(*b*). In the *Observatory* for January the Astronomer Royal for England called attention to a remarkable diminution of the brightness of the *Nova*. He said: "The photographs [for

magnitude] were discontinued at Greenwich on September 6, and the *Nova* was noted as invisible in the 10-inch finding telescope about October 7 by Mr. TURNER, October 22 by Mr. DAVIDSON, and on October 25 by Miss EVERETT. This would imply that the *Nova* was below the 14th magnitude. * * * On November 30 it was estimated by Mr. TURNER and Mr. DAVIDSON as 0.9 magnitude *brighter* than the comparison star, so that it would appear to have risen between October 25 and November 29 from below the 14th to about 8.5 magnitude, and this is the second time such a brightening has been noted."

The above results are widely at variance with those secured here and elsewhere during October. I observed it visually with the 4-inch finder on October 12, 19 and 22, and spectroscopically with a grating on October 12 and 19, and no significant decrease in brightness was detected. Prof. BARNARD observed it with the 36-inch on October 21, 23 and 25. In his opinion, since August the object has "as a whole remained essentially constant in its light." At Oxford, England, on October 5, 7 and 10, the magnitude was estimated at 9.5; on October 19 at 9.7; and on October 25 at 9.8. It is impossible to harmonize the observations made here and at Oxford with those made at Greenwich on the same nights, unless, indeed, we grant that the *Nova* varied 4.5 magnitudes in a few hours. If it is granted that such a variation has occurred, it must have very great significance in the finally accepted theory of the *Nova*.

(*c*). In *Astronomische Nachrichten* No. 3129 and *Astronomy and Astro-Physics* for January, Herr EUGEN von GOTHARD compares, in an interesting manner, the spectrum of *Nova* with the spectra of eight well-known planetary nebulæ. As had already been found by observations made here, the spectra of the *Nova* and of the nebulæ are practically identical. Herr von GOTHARD'S observations were made photographically in September and October in a novel way. In front of the 10¼-inch reflecting telescope already arranged for ordinary stellar photography he placed a thin 10-inch-square prism. The image of the *Nova* formed on the sensitive plate was its spectrum, of which eight bright lines were recorded by long exposure. Not using a slit spectroscope, he was of course unable to measure the velocity of *Nova* in the line of sight. The small dispersion employed gave a spectrum only 3 mm. long from λ 580 to λ 373, and

hence the wave lengths could not be measured accurately. The wave lengths of the bright lines photographed he gives as below:

Nebulæ.	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
G. C. No. 4447 . . .	—	502	—	434	411	396.5	386.5	373
" 4964 . . .	—	501	470	434	409	397	386.5	—
" 4373 . . .	—	502	—	434	410	396.5	386.5	373
" 4514 . . .	—	502	—	434	410	396.5	385.7	371
" 4628 . . .	—	501	468	434	408.5	396	386.5	372
N. G. C. No. 7027 . . .	—	500.7	464	434	410	395	385.7	—
" 6891 . . .	—	502	—	434	410	396	386.5	372
" 6884 . . .	—	500.5	—	434	—	395	386.5	—
Nova	582	500	464.2	434	407.7	395	385.5	372

The line λ 582 is the same line observed by me at λ 5750. It does not appear in the nebular spectra preceding, and is not known to exist in any other spectrum.

Herr von GOTHARD calls attention to the very different intensities assigned to the bright lines by himself and by me, and suggests that they are due to the very general absorption of the violet rays by the 36-inch objective. The true explanation, however, is entirely different. My estimates are *visual*, while his are *photographic*, and based upon the very peculiar curve of sensitiveness of orthochromatic plates. The brightest line shown on my photographs is that at λ 4360, as it also is on his plates, though he assigns a wave length 4340 and uses it as the origin of measurements for the whole spectrum. If to this line he assign the correct wave length 4360 the apparently erroneous position of the line H δ (λ 4077) is explained.

The results of the studies have been summarized as follows by von GOTHARD:

(1). The spectra of the planetary nebulæ agree typically, although they differ slightly in the intensities.

(2). Hydrogen is represented in each spectrum by three or more lines, viz: λ 434, λ 410, λ 397.

(3). Besides the hydrogen lines the presence of two characteristic nebular lines λ 5006 and λ 3867 can with certainty be proved in all, a third λ 3727 in most spectra. The fourth line λ 464–470 seems to be less frequent.

(4). Line λ 3727, which is always very intense in the large irregular nebulæ, is always very faint in the true planetary nebulæ, which fact marks a considerable difference between the two kinds.

(5). In each spectrum can be detected a more or less developed continuous spectrum, corresponding to a nucleus or a condensation.

(6). The physical and chemical state of the new star resembles at present that of the planetary nebulæ.

From observations made here, at Harvard and elsewhere, all of these results were well known except the fourth; and that is just the opposite of what would naturally have been expected from Dr. HUGGINS' photographs of the *Orion* nebula spectrum. He found that this line λ 3727 was relatively much brighter for the condensed portions of the nebula than for the diffused.

(*d*). I have remeasured the position of the yellow line, in connection with some work on WOLF-RAYET stars, and have obtained for it:

1893, February 15 . . . λ = 5752,
" " 18 . . . λ = 5751.

The finally adopted wave lengths for the yellow lines in the WOLF–RAYET spectra will differ very little from 5876, 5813, 5692 and 5594.

(*e*). There are several additions and corrections to be made to the list of wave lengths as published in the last number of the *Publications*. The amended list is given below. Those marked thus (*) were determined by Mr. TOWNLEY:

1892, Dec.	13*	λ = 5004.2	Velocity = — 107 miles.
"	14*	5004.1	— 109
"	18*	5006.3	— 29
1893, Feb.	10	5006.2	— 30
"	14	5006.1	— 33
"	27	5005.7	— 52

In Mr. TOWNLEY'S observing notes I find: for December 13, "wind nearly 60 miles per hour," observations few and discordant; for December 14, "wind 50 miles per hour," observations discordant; and for December 18, "very little wind," observations very accordant, adjustments tested on solar spectrum next morning. It is evident that the observations of December 13 and 14 are entitled to very small weight. It is quite probable that the wave lengths were considerably larger in the two months when no observations were made.

In any discussion of these observations it is necessary to take into account the difficulty of accurately bisecting a line as broad and diffuse as this one is. The error in the result for any night can scarcely exceed 10 miles per second, and there can be no doubt of the reality of the change in wave length. If it is due to orbital motion, a very unusual orbit will be required to satisfy the observations.

(*f*). A recent note in *Astronomische Nachrichten* by Dr. HUGGINS describes the chief nebular line of *Nova's* spectrum as multiple, consisting of several fine bright lines very close together.

On August 30 this line was suspected to be double, at Mt. Hamilton, and on September 7 the line was thought to have a still different form. Later observations did not confirm my suspicions. On November 7 it was examined under the great dispersion of a fourth order grating and seen to slope equally and uniformly in both directions.

(*g*). Two very important contributions to the spectroscopic history of the *Nova*, during February and March, 1892, have recently been published: one by Herr A. BELOPOLSKY of Pulkowa in the *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg*, and the other by Father SIDGREAVES of the Stonyhurst Observatory (England) in the *Memoirs of the Royal Astronomical Society*. Both papers contain very extensive lists of bright and dark lines. Between the several catalogues of observed wave lengths obtained by different observers there is not that degree of accordance which could be wished for. However, there is a better agreement than at first appears. Many apparent discrepancies are removed by considering that in this spectrum a large number of lines shown to be single under weak dispersion are shown to be multiple under strong dispersion. The wave length given by one observer will frequently for this reason be found to be the mean of the wave lengths for two or more finer lines measured by another observer.

The observations of Herr BELOPOLSKY certainly support the theory that the *Nova* consisted of two or more bodies moving with very different velocities, while Father SIDGREAVES considers that his observations argue in favor of the one-star theory of *Nova*.

(*h*). Micrometer observations made by Prof. BARNARD on several nights since August to determine whether the *Nova* was

moving with reference to the small stars near it (see *Astronomiche Nachrichten* No. 3143) make it probable that a very slight displacement has occurred; too slight, however, to say that the observed variations are not due to unavoidable errors of observation.

EVOLUTION OF THE DOUBLE-STAR SYSTEMS.

By Dr. T. J. J. See, University of Chicago.

[Abstract of a paper read before the Chicago Academy of Sciences, February 7, 1893.]

Sound cosmogonic speculation begins with Kant, who was the first of modern philosophers to advance a definite mechanical explanation of the formation of the heavenly bodies,* and particularly of the bodies composing the solar system. The views of Kant do not seem, however, to have received much scientific recognition until after Laplace's independent formulation, in more exact mathematical terms,† of a similar explanation of the origin of the planetary system, based upon remarkable phenomena observed in the motions of the planets and satellites, and known as the nebular hypothesis.

Partly on account of the overwhelming‡ argument of Laplace in favor of a *natural* or *mechanical* explanation§ of the origin of the planetary system, and the sound dynamical conception underlying the great geometer's hypothesis, and partly on account of the keen interest and speculation arising out of Sir William Herschel's epoch-making investigations of the nebulæ, the nebular hypothesis was soon accepted by astronomers as an explanation entitled to scientific belief. The classic researches of Sir John Herschel tended still further to establish confidence in Laplace's view of the nebular origin of the heavenly bodies; but when Lord Rosse's great reflector showed the discontinuous

* See Kant's *Allgemeine Naturgeschichte und Theorie des Himmels*, published in 1755; *Sämmtliche Werke*, Vol. I, p. 207.

† See *Système du Monde*, Note VII et dernière, p. 498.

‡ See Laplace's remarks in the introduction to his *Théorie Analytique des Probabilités*, p. 67.

§ Newton regarded the planets as having been set in their orbits by the immediate hand of the Deity, and held that the fixed stars had been intentionally placed at such vast distances apart in order that they might not fall upon one another by their mutual gravitation. See his remarks in the *Scholium Generale*, p. 527, of Sir William Thomson's edition of the *Principia*.